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ON THE THROUGHPUT OF CHANNEL ACCESS ALGORITHMS WITH LIMITED SENSING*

by

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ABSTRACT

This document ~~We~~ consider access protocols for Aloha type multiaccess channels. It ~~We~~ argue, and show in an important case, that they can be modified to allow new transmitters to join the system at arbitrary times. This feature, known as "limited sensing" or "free entry", does not reduce throughput performances. In the case presented, the modified algorithm is also robust with respect to feedback errors.

Additional keywords: Naval research.

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We consider access protocols for Aloha type multiaccess channels. We argue, and show in an important case, that they can be modified to allow new transmitters to join the system at arbitrary times. This feature, known as "limited sensing" or "free entry", does not reduce throughput performances. In the case presented, the modified algorithm is also robust with respect to feedback errors.

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ABSTRACT

We consider access protocols for Aloha type multiaccess channels. We argue, and show in an important case, that they can be modified to allow new transmitters to join the system at arbitrary times. This feature, known as "limited sensing" need not reduce throughput performances. In the case presented, the modified algorithm is also robust with respect to feedback errors.

EXTENDED ABSTRACT

We consider the classical Aloha type multiaccess channel where packets are generated at a large number of sites and are eventually transmitted on a common channel. Overlapping transmissions result in a collision and all the packets involved must be retransmitted. Transmitters monitor the activity on the channel and obtain some type of feedback information, depending on the precise model at hand.

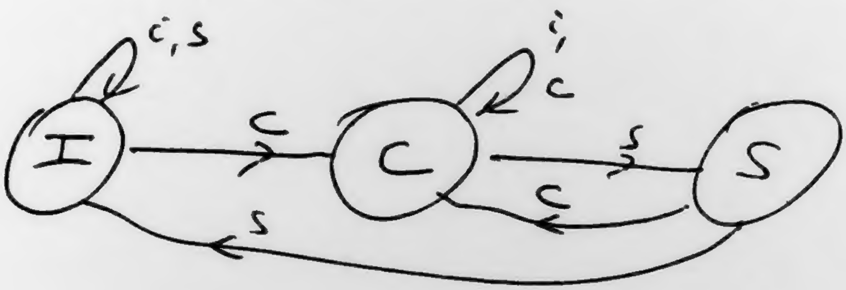
The problem is to design protocols that exploit feedback information to schedule transmissions so as to maximize the achievable throughput and/or cause little average delay for a given throughput. The algorithms with the best performances require all transmitters to monitor the channel at all times. Some attention has also been devoted to channels with "limited sensing" where a transmitter only monitors the channel while it has a packet ready for transmission. The words "free access" are used to denote "limited sensing" algorithms where a packet MUST be transmitted immediately following its generation.

"Limited sensing" algorithms have practical advantages over algorithms that require continuous observations. The "Free access" characteristics on the other hand does not seem to be as important, except that it guarantees minimum delay in very light traffic. All the "limited sensing" algorithms described previously exhibit achievable throughputs lower than those achievable by algorithms monitoring the channel continuously [Tsybakov, Vvedenskaya], [Mathys], [Georgiadis,Papantoni-Kazakos].

This situation is rather unexpected ! As there is no requirement that delay be kept small, a transmitter can listen to the channel for a long time before transmitting a generated packet. Doing so should put it in a "state of synchronization" close to what it would have had by listening to the channel since the beginning of operations.

We cannot show at this time that in general limited sensing does not reduce achievable throughput. We will only illustrate our contention for the slotted channel with ternary feedback. There packets are only transmitted in predefined slots and transmitters can learn immediately whether zero, one, or more than one transmissions took place in a slot.

The best known algoritms for that channel are variations of Gallager's algorithm. For our purpose we view them as having three phases of operation, as illustrated in the figure below. There letters label the channel outcomes associated with phase transitions.



In phase I the algorithm allows transmissions from a set T of transmitters for which only a priori statistical information is available. It immediately returns to phase I (choosing another set) if no collision occurs, else it moves to phase C. In that phase set T is partitioned into subsets L and R, and only transmissions from L are allowed. An outcome of idle means that R must contain at least two active transmitters. The algorithm abandons L, partitions R and continues in phase C. A collision outcome for L implies (under Poisson statistics assumption) that only a priori information is known about transmitters in R. The algorithm partitions L and remains in phase C. After a success in phase C the algorithm moves to phase S where transmissions from R are allowed. The next phase is C or I, depending on the outcome, which cannot be "idle".

It has long been recognized that the phase of the algorithm can sometimes be determined by observing the transmission outcomes. After hearing a collision on the channel one can immediately conclude that the algorithm is in phase C. Similarly a success followed by another success or by an idle unambiguously signals a return to I. Only long strings of idles cause ambiguity as they can occur both in the I and C phases.

We suggest modifying the algorithm to force a collision after n-1 idles in phase C (for some $n > 1$) by allowing transmissions from the entirety of set R (a similar method has been proposed [Ryter] to recover from some feedback errors). This modification guarantees that new listeners will be "in phase" within at most n slots, while reducing the achievable throughput by occasionally wasting a slot. This throughput reduction vanishes exponentially fast with increasing n. As a side effect of the modification, the algorithm that we propose below is also robust with respect to feedback errors that can cause Gallager's algorithm to deadlock. In the case $n = 2$, no effective distinction is made between the outcomes of "idle" and "success", so that the algorithm only requires binary feedback [Mehravari,Berger].

Now that we can synchronize new listeners, it is a simple matter to make limited sensing work. We will allow "new" transmitters to transmit only when the algorithm is in the I phase and we will let transmissions be essentially Last In First Out, as in many protocols with limited sensing. Thus "old" transmitters, which have more information, defer to "new" transmitters in such a way that the properties of the original algorithm are preserved. Imagine that an observer watching the channel since the beginning of operations has iteratively produced the following picture of the time axis:

```
xxxxxxx.....xxxxx....RRRL..xxxxLLLLxxxxxx...ssss      - time
0                                              !
                                           current time
```

```
packets generated in sssss are synchronizing (with a priori stat.)
   "         "     "  .....  are synchronized (still with a priori stat.)
   "         "     "  LLLLL form the L subset (phase C)
   "         "     "  RRRRR form the R subset (phases C and S)
   "         "     "  xxxxx have been successfully transmitted
```

(The sets LL and RR appear above in keeping with the Last In First Out spirit. This feature is by no means necessary.)

As transmissions take place current time is advanced. The sss set is extended to the right, while its left part is possibly updated into ..... The LLL set is updated into xxx (upon idle or success) or split into LL and RR (upon collision). The RRR set is returned to .... (upon collision) or split into TT and RR (upon idle). When the algorithm reaches the I phase a new set T is selected from the .... set, starting at the left boundary of the updated ssss set, in an Last In First Out fashion. For example if the LL and RR sets in the previous figure each contained one transmitter, the new figure might be

```
xxxxxxx.....xxxxx....xxxx.TxxxxxxxxxxxxxxxTTTTTTTTs      - time
0                                                  !
                                           current time
```

Observers that have joined the channel at some time can recreate the part of the previous picture to the right of their arrival time, so that in particular transmitters can decide to what set they belong and if they must transmit.

Conclusions about achievable throughputs and delays can readily be obtained from existing results on the original algorithms.

We believe that existing access algorithms for other types of feedback can be similarly transformed to use limited sensing only, while degrading achievable throughput by arbitrarily small amounts, at the expense of some extra delay.